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(71) Applicant: NANOPIERCE TECHNOLOGIES, INC. [US/US]; Suite 3580, 370 Seventeenth Street, Denver, CO 80202 (US).

(72) Inventors: NEUHAUS, Herbert, J.; 770 Maroonglen Court, Colorado Springs, CO 80906 (US). WERNLE, Michael, E.; Ottobrunner Straffe 76, 85635 Hohenkirchen (DE). BLUM, Frederick, A.; 1412 North Wahsatch, Colorado Springs, CO 80907 (US). KOBAR, Michael; St. Johannes Strasse 1, 85625 Glonn (DE).

(74) Agent: HATTENBACH, Brad, J.; Dorsey & Whitney LLP, Suite 4700, 370 Seventeenth Street, Denver, CO 80202 (US).

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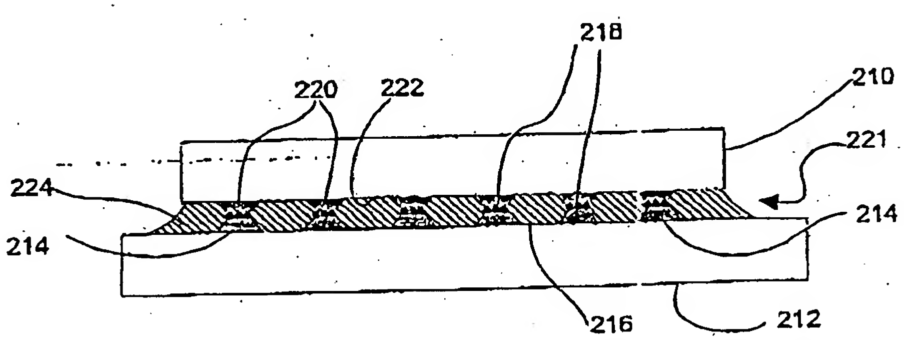
(54) Title: METHOD FOR ASSEMBLING COMPONENTS AND ANTENNAE IN RADIO FREQUENCY IDENTIFICATION DEVICES



(57) Abstract: The invention provides a method for permanently physically and electrically attaching the electrically conductive contacts (220) of a first component (210) in a RFID device, such as a smart card or smart inlay, to the electrically conductive contacts (214) of a second component (212)of the device. Attachment is made between the first and second components of the device by co-depositing metal and electrically conductive hard particles (218) upon the conductive contacts of either the first (210) or second (212) components and using a non-conductive adhesive (224) to provide permanent bond between the components (210) (212) and their conductive contacts (220) (214). Components (210) (212) of an RFID device may include, for example, a memory chip, a microprocessor chip, a transceiver, or other discrete or integrated circuit device, a chip carrier, a chip module, and a conductive area, e.g., an antenna.

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solution except for the particles. The substrate with the nickel-particle plate is again rinsed in deionized water 1660 after the second nickel plating treatment.

Immersion gold is a typical finishing step 1662. The process differs from the autocatalytic nickel plating in both its mechanisms and its results. An immersion gold process actually replaces nickel molecules on the surface of the second nickel plate for gold molecules, resulting in a thin gold layer. Oromerse MN (Technic, Inc., Cranston, RI) propriotary solution may be used. While the second nickel plating provides a conductive pathway and the robust mechanical bonding strength to secure the particles to the substrate, a finish layer of dense immersion gold ensures persistent protection from surface degradation and excellent electric conductivity over a long period of time.

The major benefit of using an electroless particle co-deposition process to attach hard particles to chip bond pads is that particle attachment can occur at the wafer level. This means that all the bonds pads of all the hundreds of chips on a wafer can be "bumped" with hard particles before the wafer is diced. There is no need for electrical isolation between any of the chips or the respective bond pads because the process is electroless. The deposition only occurs on the individual bond pads. The process is very efficient as well because only thin layers of metal are plated; the "bump" is created by the particles trapped in the metal. This is in contrast to the significant amount of time it takes to build up a metal bump by a standard electroless metal deposition process.

EXPERIMENTAL OBSERVATIONS

1. General

Extensive experiments verifying the feasibility of the present method for component attachment have been conducted at NanoPierce Technologies in Colorado Springs, Colorado and NanoPierce Card Technologies, GmbH in Munich, Germany. The experiments covering the validation for the entire process can be categorized into three groups, namely: a) particle placement on wafer, substrates, or antenna structure; a) bonding tests using various non-conductive adhesives; and c) characteristics and reliability testing for bonded components using the methods disclosed in this invention.

2. Description of materials and process used in validation test

2.1 Chip

For the development of a die bonding process for a smart inlay application, a special test chip has been developed. This chip has the same dimensions and bond pad positions like the most common chip for smart inlay applications named "I-Code," which has been

developed by Philips. This test chip is configured for only measurement purposes and contains two 4-point-Kelvin structures for contact resistance measurement and an additional daisy-chain structure for further qualification.

2.2 Substrate

The test substrates selected for the chip attachment test were similar to those commonly used in smart card and smart inlay applications. Both rigid board and flex circuit substrates were chosen. The test substrates include rigid board with copper tracks, rigid board with Ni/Au plated copper tracks, flex circuit with copper structures, and flex circuit with aluminum structures.

2.3 Adhesives

In order to achieve the greatest reliability, screen tests utilizing various adhesives on different substrates were performed. The following specific criteria for the selection of the adhesives was determined in order to search for an adhesive with highest bonding reliability and greatest electrical performance. The criteria include:

- fast curing at a low temperature;
- low moisture absorption;
- relatively high shrinkage during curing;
- a compatible thermal expansion coefficient with the chip and substrate; and
- enough hardness upon cure that movement between the chip and substrate is prevented;

The adhesives considered in the screen tests include cyanoacrylate adhesives, epoxy-based adhesives, UV light curing acrylate-based adhesives, and light activated epoxy-based adhesives.

3. Particle Placement Process

Two particle placement methods have been indicated in this invention, namely a modified electrolytic plating method and a modified electroless method. For the chips used in the test, the two-step electroless process as disclosed in U.S. Patent Application Serial No. 09/883,012 entitled "Electroless Process for the Preparation of Particle-Enhanced Electric Contact Surfaces," filed 15 June 2001 was used. The detailed procedure for the particle placement is as the following.

The wafer was cleaned by alkaline solution at 135°F for 3 minuntes, followed by etching in 50% nitric acid. The wafer was then zincated in a Fidelity 3116 (Fidelity Chemical, Newark, NJ) solution for 20 seconds. The wafer was again etched in 50% nitric acid, followed by a second zication (often refering as double zication) in the Fidelity 3116

solution for another 10 seconds. After the double zication, the wafer was immersed into a Fidelity 9002 (Newark, NJ) proprietary nickel solution for 3 minutes. The nickel-plating solution contained 6 to 12 micron sized diamond particles (GE Superabrasive, Worthington, OH) at a solid concentration of 0.5%. After the particles were plated on the wafer, the wafer was activated by a Fidelity 9025 (Newark, NJ) proprietary palladium solution. Another layer of nickel was then plated by Fidelity 9002 (Newark, NJ) proprietary nickel solution, followed by an immersion gold finish process. A representative particle-enhanced wafer bond pad is shown in Figure 17.

4. Chip bonding process

Chips were bonded to the different substrate materials to determine the bonding force for the reliability test. The chip was taken manually out of the gel pack and placed face down onto a presentation substrate for the die bonder. From this presentation substrate the die bonder picks the chip with a programmable force and delay time. With a beam splitter optic, the chip was aligned to the substrate by hand. The adhesive was dispensed manually by a pin transfer. Then the chip was bonded to the target substrate with defined bond force and pressure time. The die bonder used in the test could heat the bond tool up to 300°C. For the final curing of the adhesive, the fully assembled test boards were placed in an oven for the required time at 150°C.

During the die bonding process a certain force had to be applied so that the particles on the particle-enhanced surface could penetrate into the conductor of the opposite contact site. By pressing the chip onto the rigid test substrate with different forces, the minimum bond force was determined when all of the 10 bond pads had a contact to the substrate. By adding an additional force for safety reasons the optimal bond force for the rigid test substrate was set at 250 grams. By calculating the bond force per bond pad, assuming that the relative contact force is uniform over all pads, the large pads have a bonding force of approximately 50 grams and the smaller pads of approximately 20 grams. This is relatively low in comparison to anisotropic adhesive bonding and to the stud bumping process, which for similar sized bond pads required bonding forces of about 100 grams for the large pads and 50 grams for the small pads.

At the flex substrate with the aluminum tracks the bond force could be lowered to 100 gram without a significant increase of the contact resistance. At a bonding force of 50 gram an increase of the contact resistance was visible. Further test are being performed on this effect.

For the tested adhesives the following bond parameters have been used:

Process	Adhesive		
	Threebond 2217H	Threebond 2271B	EPO-TEC 353 ND
Pick	16 gr, 50 ms, 150°C	16 gr, 50 ms, 150°C	16 gr, 50 ms, 130°C
Dispens	Manual pin transfer	Manual pin transfer	Manual pin transfer
Place	250gr, 10 s, 150°C	250gr, 15 s, 150°C	270 gr, 15-20 s, 130°C
Cure of adhesive	150°C, 5 min in oven	150°C, 2 h in oven	150°C, 5 min in oven

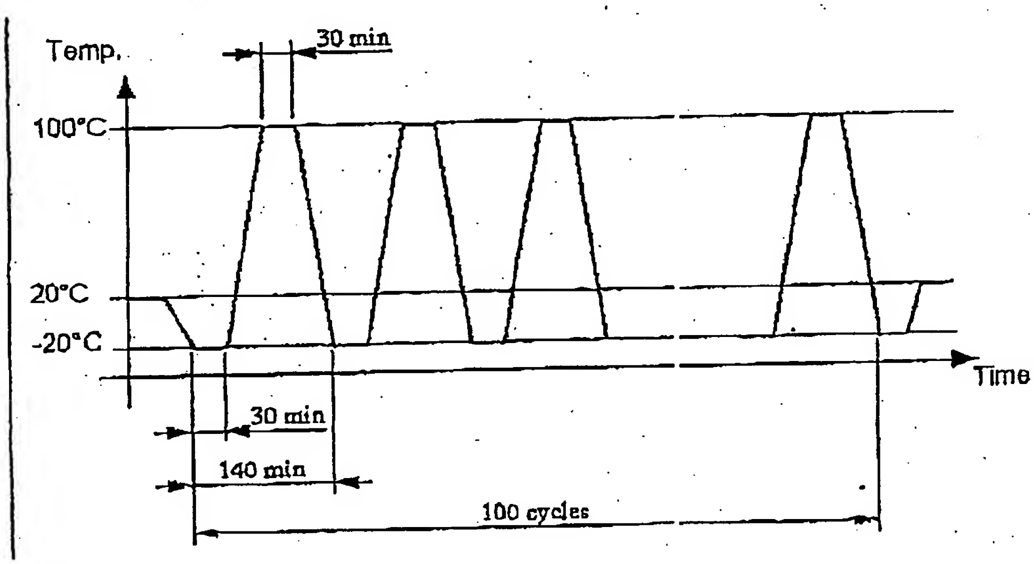
Process	Adhesive		
	Threebond 22X-330	Threebond 3372C	
Pick	16 gr, 50 ms, 150°C	16 gr, 50 ms, 150°C	
Dispens	Manual pin transfer	Manual pin transfer	
Place	250gr, 10 s, 150°C	250gr, 10 s, 150°C	
Cure of adhesive	150°C, 10 min in oven	150°C, 1 h in oven	

After curing the adhesive a shear test was executed at the half of the samples to determine the shear strength of each combination. The other half of the samples was stressed at temperature cycles and then a shear test executed. The tests brought the following results:

Type of adhesive	Rigid board	Flex circuit
Cyanoacrylate (3 types)	Didn't meet the requirements due to a large mismatch at the thermal expansion coefficient and a low operation temperature limit	Didn't meet the requirements due to a large mismatch at the thermal expansion coefficient and a low operation temperature limit
Epoxy based adhesive (4 types) cured by increased temperature	Good results at shear strength, but require a relative high curing temperature and long bonding and curing time	Good results at shear strength, but require a relative high curing temperature and long bonding and curing time
UV light curing acrylate based adhesive	Could not be cured on rigid board because UV light doesn't pass the substrate nor the chip	Relatively good bonding performance, but not fully cured at areas with the conductive tracks (shadow)
Light activated epoxy based adhesive	No curing because of chemical inhibition of the adhesive caused by rigid board	Excellent bonding performance and very fast curing

5. Tests

All the samples were subject to optical inspection before being electrically tested. An Agilent 34420A nano-voltmeter was used to measure the contact resistance. Among the test samples, particle-enhanced chips were bonded to the two rigid substrates using three epoxy-based adhesives respectively. For comparison, additional dies with out particle-enhancement were also assembled to the rigid substrate with Ni/Au finish using either an anisotropic conducting adhesive, an isotropic conducting adhesive, or a solder bond. After measurement of the initial contact resistance, the samples were stressed by temperature cycling. The samples were measured again every 100 temperature cycles. The major parameters in the temperature cycles are shown in the graph below.



The measurement of the contact resistance brought the following results:

1) The particle-enhanced contacts could penetrate copper oxides easily.
2) The contact resistance between the chip and the rigid board with the copper tracks is lower than at the Ni/Au plated boards. The average resistance is approximately 10 mOhms for the copper track contacts and 20 mOhms for the Ni/Au finished boards.
3) The contact resistance remained constant over more than 400 temperature cycles, which indicates good reliability for the test sample made using the method disclosed in this invention. The test is still ongoing.

4) Although there were small differences between the contact resistances for the contacts made using various adhesives, the contacts made by non-conductive adhesive with particle-enhanced surfaces are on the same level with untreated surface boding by anisotropic adhesive and solder connections.

5) Isotropic conductive adhesive, as used in the comparative samples, is not usable at chips with bond pad pitches of 200 microns or less.

CONCLUSION

The method and products provided in accordance with the present invention have a number of advantages over the prior art. First, only a low bonding force is needed during and after the chip or chip module is bonded to a substrate or antenna structure, since the sharp, pointed, hard particles can easily penetrate the conductive contact surface. This low residual stress on the chip or chip module compared to the high stress incurred in conventional chip attachment methods, such as conductive adhesive bonding, allows thinner chips or chip modules to be used to make smaller, more flexible, mobile RFID devices, such as smart cards and smart inlay devices.

Second, to the cost of manufacturing the cards and labels is significantly reduced by the elimination of manufacturing steps and the use of less expensive materials.. Because high temperatures are not employed in connecting components—as in soldering or wire bonding—a simple, inexpensive substrate material can be employed, for example, polyvinyl chloride, polyethyleneterephthalat ("PET/PETP"), glycol-modified PET ("PET-G"), acrylonitrile-butadiene-styrene copolymer ("ABS"), polystyrol ("PS"), polyproplyne ("PP"), cellulose or paper and blends, laminates, or co-extruded combinations of these materials. These materials can also be printed easily. No special handling or curing steps are required.

Third, if the chip bond pads are particle-enhanced, it is possible to make a design arrangement so that the placement of the chip is not very critical. In contrast, when conductive adhesives are employed, the printing of the adhesive on the chip must be very precise, because the chips are small. With the present invention, simpler, less expensive manufacturing equipment that can be used and operated at higher speeds. In addition, manufacturing of the card or label is simplified in that non-conductive adhesives can be applied rather indiscriminately without concern for the viability of the electrical connection between the components being bonded. The advantage is more significant for small components and pitch distance attachments. When compared to isotropic conductive adhesive, the printing or dispensing of non-conductive adhesive is much simpler, as there is

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